CHAPTER 8

ELECTRICAL POWER SUPPLY, DISTRIBUTION, AND UTILIZATION SYSTEMS

8-1. GENERAL. Electrical design for projects includes all tasks required to produce construction plans and specifications for the project as described in the project criteria documents or as stated in the A-E scope of work.

8-2. PURPOSE AND APPLICABILITY. The purpose of this chapter is to provide guidance for preparing accurate and complete electrical designs that are cost effective and energy efficient, and are inherently reliable and safe. The guidance and requirements contained herein are applicable to all A-E's and contractors for design projects under the direction of USAEDH. The designer also must comply with the instructions provided in chapter 1, General Instructions, and chapter 2, Presentation of Data.

8-3. REFERENCE DOCUMENTS. The documents listed below are directly related to electrical power supply, distribution, and utilization systems designs. The latest copy of the documents listed will be used. Designers are required to become familiar with the requirements in these documents and ensure compliance where applicable.

a. AR 415-10, General Provisions for Military Construction

b. AMCR 385-100, Safety Manual

c. ER 1110-345-100, Design Policy for Military Construction

d. ER 1110-345-122, Interior Design

e. ER 1110-345-700, Design Analyses

f. TM 5-809-10, Seismic Design for Buildings

g. TM 5-811-1, Electrical Power Supply and Distribution

h. TM 5-811-2, Electrical Design, Interior Electrical System

i. TM 5-811-3, Electrical Design, Lightning and Static Electricity Protection

j. TM 5-811-4, Electrical Design, Corrosion Control

k. TM 5-811-5, Army Aviation Lighting

l. TM 5-811-6, Electric Power Plant Design

m. TM 5-811-7, Electrical Design, Cathodic Protection

n. TM 5-811-14, Coordinated Power Systems Protection

o. CE Guide Specifications

p. CE Standard Detail No. 40-06-04, Lighting Fixtures

q. American National Standards Institute, ANSI C-2, National Electric Safety Code

r. Institute of Electrical and Electronic Engineers (IEEE) Publications

s. National Electrical Manufacturers Association (NEMA) Standards

t. National Fire Protection Association Publications, (NFPA 70)

u. National Electrical Code (NEC) Standards

v. Underwriters Laboratories, Inc. (UL) Standards

w. Occupational and Safety Health Act Standards, Title 29, Code of Federal Regulations, Parts 1910 and 1926

x. MIL-HDBK-423, High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based Facilities

y. MIL-STD-188-125, High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions for Common Long-Haul/Tactical Communication Systems

z. USAF Handbook for Design and Construction of HEMP/Tempest Shielded

8-4. GENERAL DESIGN INFORMATION AND GUIDANCE

a. Design Documents. Designs will include, but not be limited to, drawings, specifications, design analyses, and studies which define construction requirements in sufficient detail to ensure the proper and rapid installation of electrical materials and equipment. Energy conservation and life cycle cost design features will be reflected in the Energy Conservation and Life Cycle Cost Design Analysis specified in chapter 1. Extreme care should be used to avoid ambiguity on design drawings and in project specifications.

b. Design Criteria. The A-E or contractor must prepare designs IAW guidance contained in the applicable Department of Army technical manuals, documents referenced in this manual, and guidance contained in this chapter. Designers will ensure that designs conform to the project criteria, except when the criteria conflicts with design guidance, directives of USAEDH, unless directed by USAEDH. Significant deviations from design guidance, from CE guide specifications, and from standard CE drawings are subject to approval by USAEDH.

c. Design Analyses. Designs will be fully substantiated by analyses, calculations, and narratives which explain design philosophies and selection alternatives. See paragraph 8-6 through 8-8 for complete information.

d. Specifications. Electrical specifications will be prepared by the designer in accordance with chapter 3, Project Specifications.

e. Review and Approval. Designs will be subject to review and approval of USAEDH and by technical organizations which represent the Using Agency. Designs may also be subject to review and approval by commercial power utilities officials or by other Government agencies which control or use the same systems associated with the design.

f. Safety Requirements. Designs will conform to personnel safety requirements in the documents listed above and will incorporate provisions for safe installation, operation, and maintenance of equipment. Designs will incorporate the applicable provisions of the Occupational Safety and Health Act as set forth by the Code of Federal Regulations 1910 and 1926. Electrical designs will be fully coordinated with the project designs of other engineering disciplines and architects to ensure that adequate clearance and access space is provided.

g. Special Materials and Applications. Designs will address and include provisions for specialized applications including specialized materials or equipment mountings.

h. Short-Circuit and Protective Device Coordination Studies. The designer will define the scope of the system protection and the coordination required for the electrical system. The studies will demonstrate that the equipment ratings and coordination of protective devices provide a safe system in accordance with NFPA 70 and ANSI C2. The studies will include the following: (1) a complete single-line diagram of the power system showing all devices which contribute fault current and those which must be coordinated; (2) a short-circuit study including the maximum and minimum values of short-circuit currents at major buses extended down to system buses where currents are equal to 10,000 amperes symmetrical; (3) utility company data including system voltages, fault MVA, system X/R ratio, time-current characteristics and settings, and existing power system data including time-settings; (4) fully coordinated composite time-current characteristic curves including recommended ratings and settings of all protective devices in tabulated form; and (5) associated calculations to demonstrate that the power system protection will be selectively coordinated by the use of devices or equipment selected. Situations where system coordination is not achievable due to device limitations will be noted. The studies will be performed by a registered professional engineer with demonstrated experience in power system coordination within the last three years. See TM 5-811-14 for guidance.

i. Hardened Facilities. Hardened facility designs will incorporate special design considerations for shielding, filters, shock, and vibration.

(1) Hardened designs will conform to the provisions of MIL-HDBK-423 and MIL-STD-188-125.

(2) Specialized equipment and material requirements will be specified and shown. Complete mounting details will be provided.

(3) Calculations will be included in the design analyses to demonstrate that the specified equipment and materials will withstand the design basis forces.

j. Hazardous Facilities. Hazardous facilities require special design considerations for selection of electrical equipment and materials to prevent undue hazards to personnel and facilities which would be created by the presence of corrosive materials, explosives, fire, lethal gases, or as detailed in NFPA 70. AMCR 385-100 will be used for designing facilities classified as hazardous where non-nuclear munitions materials are manufactured, processed, stored, handled, or transported within a facility. The safety requirements of the American Petroleum Institute (API) may be imposed as design requirements for facilities associated with petroleum products, or for the conversion of one energy form into another. Design criteria, guidance, and directives associated with the electrical design of hazardous facilities will be listed in the project criteria documents.

k. Facilities Subject to Seismic Effects. The effects associated with seismic zone classifications will be incorporated into the design of new facilities and the modernization or expansion of existing facilities. Designs will conform to applicable requirements of chapter 7, Structural, and TM 809-10.

8-5. ELECTRICAL DRAWINGS. Standard Corps of Engineers detailed drawings will be furnished (if available) to the designer and will be used to depict construction or installation requirements. The designer will develop other drawings required to show the complete design and construction requirements. Drawings prepared by the designer will be consistent with the provisions of chapter 2, Presentation of Data. Drawings are not limited to, but will include, the following types of drawings when related to the design requirements.

a. Single-line diagrams.

b. Three-line diagrams required for annunciation, instrumentation, control, and coordinated protection of power system equipment and materials, unless omission of these diagrams is approved by the contracting officer.

c. Plans and details of electrical power systems.

d. Elementary or schematic control diagrams.

e. Power riser diagrams.

f. Schedules for power panels and panelboards.

g. Lighting and power plans, including grounding provisions.

h. Internal and external wiring diagrams, including interconnections between related items of equipment.

i. Cable and conduit schedules (when the same information cannot be adequately shown on other drawings or plans).

j. Grounding and lightning protection plans and details as required to complete the design and show applicable installation requirements.

k. Plan, elevation, side and sectional views, and details which depict installation requirements and clearances for electrical equipment.

8-6. CONCEPT DESIGN SUBMITTAL REQUIREMENTS. The concept submittal will consist of design analysis, drawings, outline specifications, and engineering studies.

a. Design Analysis

(1) General Description. The general parameters, functional and technical requirements, and objectives and provisions of the design will be described. A summary of economic factors influencing the choice of lighting, electrical supply systems, and electrical supply and utilization equipment used in the project will be provided along with an indication of how initial and life cycle costs were considered.

(2) Interior Electrical Work

(a) This analysis will include an estimate of the loads, main bus and feeder wire sizes, main switch, service entrance and transformer sizes, including proposed photometric bases. However, individual circuit load tabulations and interior voltage drop calculations are not required for the preliminary analysis.

(b) Lighting Calculations. When required by the contract scope of work, a life cycle cost analysis will be completed to support the choice of all illumination sources; otherwise, the designer will provide supporting economic data for the choice of fixtures and luminaries. Supporting data may include references to standard literature, manuals, or short-cut methods which consider first costs, energy costs, maintenance and replacement costs.

(3) Exterior Electrical Work. Voltage levels for primary and secondary distribution systems will be established and an estimate will be made concerning transformer sizes.

(4) Existing load data where connections are made to existing systems will be documented. The designer will determine the availability of sufficient capacity to carry the additional loads.

(5) Cathodic Protection. Systems and equipment requiring protection will be identified.

b. Outline Specifications. All specifications used for each project (guide or A-E prepared) will be listed.

c. Drawings. Drawings will be provided in sufficient detail so the Using Agency can visualize precisely how the designer has interpreted the functional, operational, and technical requirements. Drawings will include, but not be limited to, the following:

(1) Building Floor and Ceiling Plans. Plans will include layouts for lighting, conduits, feeders, branch circuits, grounding, and electrical receptacles. For renovation and modification projects, plans will depict the work and nonwork requirements. Where work is extensive,

separate sheets should be used to show existing-to-remain, demolition, and new work.

(2) Exterior Electrical Supply and Lighting. Electrical drawings will include plan and elevation drawings. Electrical supply and lighting layouts will show new and existing utilities. Plans will show locations of electrical supply equipment, building service equipment, and exterior supply circuits affected by new construction or renovation. The plans will be coordinated with other utility plans concerning scale, landmark references for proximity, and interference management. The plans will be separate from water, sewage, and other utility plans.

(3) Single-line Diagrams. Concept single-line diagrams will depict proposed power sources and distribution schemes (interior and exterior as applicable). The diagrams will include existing and proposed protective device types in sufficient detail to communicate the system protection philosophy.

(4) Drawings will contain nameplate data for components of existing systems which are affected by the new design or which affect the new equipment or systems.

d. Engineering Studies (as identified in the scope of work). Details for special studies required to define design and construction requirements will be submitted. The submittal will define the objective of each study, outline the study procedure, and provide technical references for development of criteria.

8-7. INTERMEDIATE DESIGN SUBMITTAL REQUIREMENTS. The intermediate submittal will be developed using the updated (in accordance with agreed upon review comments) concept design.

a. Design Analysis. Design calculations and supporting information will be submitted to support the design as follows:

(1) Voltage drop calculations will be submitted for services, feeders, and in worst-cases for branch circuits supplied by panelboards and switchboards. The source of the data (tables, curves, and short-cut methods obtained from accepted sources such as Industrial Power Systems Data Book by General Electric or Architects and Engineers Data Book by Westinghouse) must be referenced.

(2) Transformer sizing calculations will include demand loads, diversities between the demands, and loading cycles (when known).

(3) Existing load data tabulation from the previous submittal will include the method of determining the availability of sufficient capacity to carry the additional loads.

(4) Panel and Switchboard Calculations.

(a) A summary of connected loads, demand factors, and demand loads by circuit number for each panel and switchboard will be provided. This includes spare circuits.

(b) A summary of panel and switchboard demand loads, feeder sizes, diversity between panels, main switch fuse, or circuit breaker trip size, service entrance size, or service drop size will be provided.

(c) Calculations for motor feeders and motor protective devices must be submitted.

(d) Ambient temperature or conductor grouping factors considered in the selection of equipment and/or conductor sizes will be indicated.

(e) Cathodic Protection. Data and calculations will be submitted for surface areas of protected surfaces; current density requirements; number size and type of anodes to be used; size of all conductors; size of rectifier; and branch circuit calculations for the circuit serving the rectifier. Any pertinent catalog information or design criteria references will be included.

(f) Overhead electrical power line design analyses will include calculations for guy strengths, sag, and stringing tensions. Tabulations will be included on the drawings.

(g) Underground electrical power supply design analyses will include calculations of supply cable ampacities; grounding conductor ampacities; duct sizes; cable pulling; manhole and duct structural requirements; and structural requirements for support of pad-mounted equipment.

b. Specifications. Specifications for each part of the project, based on the Corps of Engineers Guide Specifications, will be submitted.

(1) Specifications will be written using the latest copy of the guide specifications. Notes to specification writers will be thoroughly reviewed before annotating or

typing. The specification writer will be most familiar with the drawings and will coordinate his work with the person(s) doing the plans to avoid discrepancies.

(2) Items not covered, or only partially covered in guide specifications, will be fully specified.

(3) Special equipment will be thoroughly described.

(4) For each luminary on the lighting fixture schedule for which there is no corresponding sheet of Standard Drawing No. 40-06-04, the designer will provide a detail on the drawings and provide a description in the specifications which is similar to the descriptions contained on the several sheets of Drawing No. 40-06-04.

c. Drawings. Design drawings will include, but not be limited to:

(1) Building Floor and Ceiling Plans. Provide layouts for lighting, conduits, feeders, branch circuits, grounding, and electrical receptacles. The configuration and location of major elements of distribution and utilization equipment will be depicted.

(2) Exterior Electrical Supply and Lighting. Elevation views of assemblies will be scaled and will identify each item of equipment arranged on the front of cabinets, compartments, cubicles, panels, and units. Electrical supply and lighting layouts, depicting exact locations with defining details will be included.

(3) Single-line diagrams. Single-line diagrams will depict power sources and distribution schemes (interior and exterior as applicable). The diagrams will show the distribution and utilization equipment and existing and proposed protective device types.

(4) Three-line diagrams required for annunciation, instrumentation, control, and coordinated protection of power system equipment and materials.

(5) Drawings or design analysis data will identify and describe existing and proposed conductors, devices, equipment, and materials by data shown on the manufacturers' nameplate data and on single-line and three-line diagrams.

(6) Elementary or schematic control diagrams.

(7) Power riser diagrams.

(8) Schedules for power panels and panelboards.

(9) Grounding and lightning protection plans and details.

d. Engineering Studies. Reports which document the research performed, descriptions and discussions of the technical issues, and a summary which defines and supports the proposed design will be included in the intermediate submittal. Submittals will include a copy of previous submittals for each study and will include updated descriptions of the study procedure and technical references.

8-8. FINAL DESIGN SUBMITTAL REQUIREMENTS. Previous submittals will be updated in accordance with approved review comments. For projects where the scope of work does not require submittals between concept and final, the final design submittal will include the requirements of any interim submittals.

a. Design Analysis. Previous submittals will be revised and updated to the final design level. All design assumptions, formulas, and equations used in the design analysis will be submitted. Short-circuit and protective devices coordination studies will be submitted as detailed in TM 5-811-14 and the notes to the designer in Guide Specification CEGS 16475.

b. Specifications. Specifications for each part of the project will be submitted. Previous submittals will be revised and updated to the final design level.

c. Final Drawings. Final drawings will show all pertinent plans, elevations, sections, details, schedules, and notes to present a complete description of the construction required. All elements to be constructed will be properly annotated and located with proper dimensions.

(1) Final exterior electrical drawings will include:

(a) Details which clearly depict the installation requirements of overhead and underground supply and utilization equipment.

(b) Clearances required by ANSI C2.

(c) Plans and details which clearly distinguish new from existing construction and define their interfaces.

(d) Equipment schedules for all equipment included in the design will be complete. A dash will be used when an entry is not applicable. Ditto marks will not be used on a schedule. Abbreviations and their definitions will be identified as a note or on a general notes sheet.

(2) Interior electrical drawings will include:

(a) A lighting fixture schedule.

(b) Complete electrical wiring details.

(c) Riser diagram indicating connections and wiring to main switch, distribution, power and lighting panels.

(d) Details for mounting fixtures and equipment.

(e) Horsepower ratings of all motors.

(f) Panelboard and switch schedule, together with connected loads.

(g) Designation of all rooms and areas as shown on architectural and other drawings.

(h) Internal and external equipment wiring diagrams, including interconnections between related items of equipment.

(i) Cable and conduit schedules (when the same information cannot be adequately shown on other drawings or plans).

(j) Electrical equipment plan, elevation, side views, sectional views, and details (interior and exterior).

(k) Interface drawings between existing electrical systems/equipment and new electrical systems/equipment (when the same information cannot be adequately shown on other drawings or plans).

(l) Nameplate data for components of existing systems which are affected by the new design or which affect the new equipment or systems (when the same information cannot be adequately shown on other drawings or plans).

(m) Equipment Schedules. Completely developed schedules for all equipment included in the design will be submitted. A dash will be used when an entry is not applicable. Ditto marks will not be used on a schedule. Abbreviations and their definitions will be identified as a note or on a general notes sheet.

d. Engineering Studies. Final reports which document the research performed, descriptions/discussions of the technical issues, and a summary which defines and supports the proposed design will be submitted. Submittals will include a copy of previous submittals for each study and updated descriptions of the study procedures and technical references.

8-9. EXTERIOR FACILITIES, UTILITIES, AND SYSTEMS. Electrical designs will conform to the requirements of AEI design criteria, TM 5-811-1, TM 5-811-3, TM 5-811-4, TM 5-811-7, TM 5-811-14, ANSI C2, and NFPA 70.

a. General Design Requirements. Designs will show and fully describe the exact point or points of interface between new systems and existing electrical systems. Existing conductors, devices, equipment, or materials required for protection against lightning and switching surges, electrical faults, and sustained overload conditions will be shown. Direct current (d.c.) power supply will be used for 'close and trip' of power circuit breakers and any motor-charging circuits unless otherwise approved. Drawings will include plans and elevations that clearly define construction interface points.

b. Aerial Line Designs. Designs for subtransmission and distribution lines will conform to the requirements of TM 5-811-1. Design drawings will contain a schedule that fully identifies and describes wood poles or other line support structures. The schedule will properly correlate with a dimensioned drawing that shows the routing of aerial lines and the details required for proper installation of the lines. The location of all line equipment, such as line-surge arresters, switching devices, and other line protection features, will be shown in the schedule and on the layout drawings for the lines. Design analyses will include all support strength calculations, guy calculations, span-length calculations, loading calculations, and moments.

c. Subtransmission Systems. Subtransmission systems are defined as those systems rated in excess of the voltage of the distribution system used to distribute power throughout the base, camp, fort, site, station, or installation.

(1) The voltage of subtransmission systems will normally be in excess of 24 kilovolts (kV) but not more than 115 kV. The design of systems rated in excess of 115 kV will require the use of the Rural Electrification Administration (REA) Form 805 titled, "Electric Transmission Specifications and Drawings." See appendix F for additional data, i.e., Pole Class Tables.

(2) Extension of commercial subtransmission lines and modifications to existing supply stations will require coordination and approval of the power company and agencies which use the same primary electrical power source. Evidence of coordination and approval will be submitted and approved by USAEDH prior to the completion of designs required by the contract scope of work.

d. Distribution Systems. Distribution systems are defined as those systems used to distribute electrical power within the boundaries of an installation through distribution cables, feeders, or lines to the distribution class of transformers.

(1) The phase-to-phase voltage rating of distribution systems range from 4.16 kV to 24 kV. Designs for new distribution systems will be 3-phase, 4-wire type except as discussed in TM 5-811-1. Normally, two-winding distribution transformers are used to reduce the distribution system voltage to a service voltage of 600 volts or less, except when utilization equipment is

rated in excess of 600 volts.

(2) The preferred distribution transformer connection configuration for secondary voltage applications of 600 volts and below is ungrounded-delta-connected primary with grounded-wye-connected secondary. The preferred distribution transformer connection configuration for secondary voltage applications above 600 volts is grounded-wye-connected primary with ungrounded-delta-connected secondary. Other types of connections for specific applications are subject to the approval of USAEDH.

e. Service Systems. Service systems will be classified as "low-voltage" when rated at or less than 600 volts, and as "medium-voltage" when services are rated above 600 volts. The exact classification will depend on the voltage rating of utilization equipment and the calculated maximum current demands for loads to be served through service-entrance conductors and associated equipment.

(1) The number of service connections should be limited to the minimum number possible. The actual number will depend on: (a) the current and voltage requirements for the particular facility or project; (b) on the availability, maintainability, and reliability requirements imposed by design criteria for nonstandard facilities; (c) by the importance of the facilities to national interests; or (d) as stated in the project authorization documents.

(2) Ground-fault current interrupting (GFCI) devices will be provided for low-voltage services when required by the National Electrical Code, or when recommended by the designer and approved by USAEDH to limit potential damage from arcing line-to-ground faults on services to hazardous facilities, or to facilities of sufficient importance to warrant the additional cost of GFCI protection.

(3) Designs for service systems will include additional protection against lightning and switching surges when either medium- or low-voltage services will supply facilities classified as hazardous, or when facilities will contain computers or essential and sensitive electronic equipment. Designs for additional protection are to conform to requirements of the NEC and AMCR 385-100.

(4) Enclosed meter sockets will be provided for each building having a connected load of 250 kVA or more to permit check metering.

(5) Medium-Voltage Services. Medium-voltage service entrance conductors and equipment will be designed only when the calculated maximum load demands for a facility exceed 500 kVA, or when the voltage rating of utilization equipment or interior substations or transformers exceeds 600 volts. These services will be 3-phase, 3-wire except when single-phase loads warrant the use of a 3-phase, 4-wire service. Such designs will normally require the use of insulated cables installed in underground raceways or interlocked armored cables installed in overhead cable trays. The recommendation of the designer, or the requirement for the use of medium-voltage services rated in excess of 600 volts, will be coordinated with USAEDH prior to beginning design.

(6) Low-Voltage Services. Low-voltage services will be designed to suit the voltage and load demands of the facilities to be supplied. Aerial designs are preferred unless underground installation is dictated by other design guidance or directed by documents referenced above.

(a) Underground installation will be required for hazardous facilities and when required for security purposes.

(b) Underground installations will be required when the calculated maximum current demands exceed 350 amperes regardless of the service voltage rating. Services should be single-phase, 240-volt, and 3-wire type for facilities with load demands of 50 kVA or less.

(c) Three-phase, 4-wire services should generally be used for load demands exceeding 50 kVA.

(d) Services rated at 120/208Y-volts will be designed only when facility load demands primarily consist of single-phase items of equipment.

(e) Designers will show the design of 480/277Y-volt services to supply equipment so rated. This includes the utilization class of transformers required to transform the 480-volt supply voltage to 120 volts or other voltages required to supply utilization items of equipment.

(7) Other Service Voltage Considerations. In less common applications, the loss of the normal service voltage may create hazards or cause important manufacturing or process activities to cease if services are solidly grounded and circuit protective devices operate to "clear" electrical ground faults. Such adverse consequences often lead to criteria requirements for the design of an ungrounded delta-type of supply. The designer will consider instead a 3-phase, 4-wire service with an impedance- grounded neutral. This approach offers the same advantage as an ungrounded-delta supply while eliminating most of the serious disadvantages. However, preference will be given to the design of a solidly grounded, 3-phase, 4-wire normal supply in conjunction with the design of an alternate power source. An alternate power source, as opposed to an ungrounded-delta service, is required by AMCR 385-100 when loss of the normal supply would create explosion or fire hazards.

f. Exterior Facilities. Designs for exterior facilities will conform to guidance for interior designs. However, special consideration will be given to exceptions with regard to the type and application of conductors, devices, equipment, and materials to be installed in an outdoor environment. Exterior facilities classified as hazardous may require special design considerations, as discussed under paragraph 8-4.

g. Exterior Lighting. Exterior lighting fixtures will be suitable for the specific application. Designers will select the most energy-efficient fixture consistent with the application. Fixtures should be the type or types included on CE Standard Detail No. 40-06-04. When standard fixtures are not suitable, similar details and specifications (in the form as those shown on the CE standard drawing sheets) will be prepared by the designer. Exterior lighting designs will conform to TM 5-811-1. The following guidance is supplementary to the TM.

(1) Designs will include provisions for automatic control of the fixtures. Controls and control circuits will allow fixtures to be automatically energized at dusk, when daylight falls to an illumination level of five (5) foot-candles or below, and to be de-energized at dawn when light increases to five (5) foot-candles or above. Automatic timers, if used, will be equipped with a four-hour minimum backup mechanism for short power outages, or photoelectric cells, or both.

(2) Outdoor lighting fixtures will be installed in an outdoor environment and will require ballasts for ballasted fixtures rated for use at temperatures below 0 degrees C. In addition the fixtures will be weatherproof.

(3) Energy conservation and subsequent demand limiting will be provided in designs by selecting the most energy-efficient fixtures for the application. Incandescent fixtures will be approved in designs only for very limited or specialized applications.

(4) Optimum use will be made of the high-pressure-sodium (HPS) type when color rendition is not important or when, in street lighting systems, a different type is advisable to distinguish intersections or entrance and exit ramps from streets or thoroughfares.

(5) Diffusers, globes, or lenses will be installed according to NEMA requirements for symmetrical or asymmetrical light distribution.

(6) The wattage rating of lamps and the corresponding volt-ampere rating of ballasted fixtures will be selected depending on the illumination levels required by the application. In general, the voltage rating for lighting circuits and fixtures will be 480/277Y-volts when the length of the lighting circuit conductors exceeds 450 feet. This will require fixtures and control devices to be rated at 277 volts.

(7) Protective/security lighting fixtures will be mounted on the sides of buildings or on the top of low parapet walls. Most other applications require fixtures to be mounted on metal or wood poles, depending on aesthetics and functional use. Fixtures installed in commercial areas, or other areas subject to view by the public, will require metal support poles which do not require painting. In an industrialized area and other areas not subject to visits by the public, fixtures will be installed on less costly wood support poles properly treated to prevent deterioration of the poles. Whenever feasible, poles used to support aerial communication cables or power feeders or lines will be used to support lighting fixtures.

(8) Designers will provide lighting fixture schedules on the design drawings, or prepare and include the schedules in the project specifications showing details of fixtures selected, including mounting type and height. Details will include electrical and temperature ratings, along with information required to ensure that fixtures will provide the type of lighting distribution required by NEMA for proper illumination. Appendix B to CE Standard Drawing 40-06-04 discusses lamp and fixture characteristics and energy conservation methods. The appendix will be used for design purposes unless superseded by more current data.

(9) Calculations will be prepared and included in the design analyses to justify the selection of fixture types and to indicate the illumination level to be achieved by implementation of lighting designs.

h. Special Considerations. Special design considerations will be required for facilities or projects of a unique nature, or when the location of projects dictates the de- sign of specialized facilities, utilities, or systems. Cathodic protection systems, hazard-ous facilities, systems rated in excess of 115,000 volts (115 kV), and locations subject to moderate-to-severe risk from lightning effects are examples of special design require-ments. Other examples are facilities containing sensitive electronic equipment, such as computers, facilities critical to national defense interests, and facilities with inherent functions that provide increased risks to the health, well-being, or safety of personnel.

8-10. INTERIOR FACILITIES, POWER SUPPLY, AND UTILIZATION SYSTEMS. Interior or enclosed facilities are generally supplied with all power requirements from one or more service-entrance conductors and equipment. However, in some instances, designers will need to specify requirements for installing batteries, converters, gen-erators, inverters, substations, etc., and automatic transfer and by-pass/isolation switches to switch between power sources, or to develop or transform power required to suit the requirements for the facility. As noted above in paragraph 8-10a, General Design Requirements, d.c. power supplies will be used for circuit breaker 'close and trip' and any motor-charging circuits unless otherwise approved. Direct current power supplies will also be used for annunciation, fire alarm, and other types of systems when operations of such essential or critical systems must be independent of the availability of a conventional alternating-current (a.c.) power source. Applicable guide specifications and applicable provisions of TM's will be used to prepare designs in those instances. However, when such guidance, specifications, and standard drawings do not exist or are inadequate, the designer will develop specialized design drawings and specifications required to complete an adequate installation, consistent with the facility requirements. These designs are also subject to the approval of USAEDH and technical organizations which represent the Using Agency. Designs for conventional facilities will include conductors, devices, equipment, or materials identified below or which relate to the equipment or systems.

a. Interior Substations, Transformers, and Ducts. Medium-voltage transformers or substations will be selected only when calculated maximum demands exceed a rating of 750 kVA, and then only after approval by USAEDH. Approval will normally be given only in instances when the magnitude of low-voltage equipment load requirements would require three (3) or more low-voltage service entrances to supply maximum demands calculated to conform to guidance provided in appendix G to this manual.

(1) Designs for facilities exceeding 50,000 square feet, and/or with demands approximating 2,000 kVA will consider the use of interior substations with low-voltage feeder and plug-in bus ducts to eliminate the need for installation of numerous motor control centers or separate motor controllers, power panels or panelboards, and associated cabling, cable trays, raceways, etc., or to reduce excessive losses. When the designer recommends installing bus ducts, substations, or power transformers, USAEDH will review the recommendation prior to beginning the design.

(2) Plug-in bus ducts, when justified, will be specified to have manually operable circuit breakers to protect circuits which serve lighting and power loads rated at or below 600 volts. Ducts will have a neutral conductor of adequate capacity when single-phase loads are served by the plug-in bus duct.

(3) Feeder ducts will have the same number of conductors as the plug-in bus duct or ducts supplied by the feeder duct. The ampacity of feeder-duct conductors will be the same as the plug-in bus duct conductors when the feeder-duct supplies a single plug-in bus duct. Otherwise, feeder-duct conductors will have the ampacity determined by the number of plug-in bus ducts served by the feeder ducts, calculated maximum demands of plug-in bus ducts, and the diversity factor assigned to the feeder duct.

(4) Demand and diversity factors will be conform to the guidance given in appendix G to this manual in relation to feeder and plug-in bus ducts. Protective devices will be specified to be installed for each plug-in bus duct served by the feeder duct when two (2) or more plug-in bus ducts are supplied by the same feeder duct.

b. Low-Voltage Service Entrances. Low-voltage service-entrance equipment will be sized for approximately 150% of the maximum current demand calculated using demand factors in appendix G. Service conductors will be selected according to the same ampacity requirements, with protective devices selected to operate at approximately 125% of the maximum current demand calculated.

(1) Service-entrance equipment includes panels equipped with up to six (6) circuit protective devices, in addition to any panel protective device or lugs used to terminate incoming service conductors. Service-entrance equipment will less commonly require the use of low-voltage power switchgear, motor control centers, switchboards, load centers, or panel boards. Equipment will be used to distribute power to other power distribution equipment, to supply power to utilization items of equipment, and to supply the utilization class of transformers required to transform service voltage to suit the rating of connected items of lighting and power utilization equipment.

(2) Equipment will be specifically listed for use as service-entrance equipment. Drawings will show the location and mountings. Service-entrance equipment will be placed on the outside of an exterior wall, or separately mounted within five (5) feet of an exterior wall, when load demands are 750 kVA or less and when the facility is served at or less than 600 volts.

(3) Lightning-surge arresters and surge-protective capacitors will be installed at the same location as the service-entrance equipment when those protective devices are required by the NEC, AMCR 385-100, or other referenced documents. In situations where it is more economical and advisable to locate service-entrance equipment within the facility and provide separate and external disconnect means, and provide surge-protective devices at the point of entrance of services into the facility, the advantages and disadvantages of the location of service-entrance equipment will be discussed in the design analyses.

(4) Deviations from the preceding general guidance will be submitted for approval to USAEDH, if equipment, devices, or conductors are required for special applications, or if higher rated and more costly equipment, protective devices, or conductors are otherwise justified.

c. Low-Voltage Power Switchgear. Low-voltage power switchgear will be specified and installed only when required by feeder load demands of 400 amperes or larger, when switchgear is more economical than other design alternatives, or as other-wise approved by USAEDH. When approved, switchgear will normally be equipped with a main circuit breaker properly rated to protect the switchgear. The main or external circuit breaker and the switchgear will be specified to have an ampere interrupting capacity (AIC) rating equal to approximately 125% of the maximum fault current calcu-lated to be available at the switchgear. Current-limiting fuses should be included in the design to protect the switchgear only when the available fault current exceeds 65,000 amperes asymmetrical.

(1) The switchgear will be equipped with a full-capacity neutral when it serves single-phase equipment in addition to three-phase equipment or loads, and will be equipped with a copper ground bus throughout the length of the switchgear. The ground bus will be equipped with suitable lugs at each end of the bus for terminating copper ground conductors up to #4/0 American Wire Gauge (AWG).

(2) The ampacity of phase buses will approximate 150% of the maximum current demands calculated IAW guidance in appendix G. Phase buses will be copper or aluminum. Specifications will stipulate that copper and aluminum buses will not be connected, if both types are provided in the switchgear, unless both types are silvered or tinned at connections, and connections are securely bolted or welded.

(3) Designs will exclude the use of molded-case circuit breakers for either the main or feeder breakers and will require that breakers be Underwriters Laboratories, Inc. (UL) listed for the specific application. Designs will require the use of either electro-mechanical or solid-state protective relays or elements which will provide proper protection for feeders and connected items of equipment, and which will allow proper coordination with protective devices to be installed on the source and load sides of the switchgear.

d. Motor Control Centers. Motor control centers will be included in designs when there are several motors and there is a need for motors to be controlled from a central location, as opposed to individual motor controllers or starters installed at or near the motor location. General guidance for the design of low-voltage power switchgear will be followed relative to the protection of motor control centers, AIC rating, and the type, number ampacity or sizes of phase, ground, and neutral buses or conductors.

(1) Starters will be specified to have circuit breakers except when the in-rush current of large motors requires the use of fused disconnect switches to prevent circuit breaker tripping when motors start. Thermal overload relays or elements will be included in the design for each phase and will be rated IAW the service factor of motors controlled and the reduced full load current caused by power factor correction capacitors or devices required for motors rated at or above five (5) horsepower (hp).

(2) Control schematics, or elementary diagrams, will be prepared by the designer and included in the design showing all control and protective devices within and external to starters and motor control centers, and associated wiring required for the proper protection and operation of motors or motor power or control circuits. Dia- grams will show the location of each device or item of equipment external to the motor control center by the use of an appropriate symbol and by descriptions on the drawings. Typical control schematics will be permitted for instances when starters have the same internal devices and wiring; when external control circuits for motors are the same; and when motors controlled are identified by name, function, and number. Typical drawings also must show other distinctions to indicate differences in starter sizes, overload

ratings, ratings of control devices, identification, setting or marking of control items, and any other differences between the typical and exact control schematics.

(3) Specifications will require that terminals of devices or equipment be wired to compartment terminal block points when it is necessary for connection to other compartment terminal block points. Specifications will also require that wiring be terminated on master terminal blocks in the motor control center for external connections to remote items of equipment or devices. Specifications will require that "spare" or "future" contacts be wired to the master terminal blocks for subsequent use.

e. Motor Selection and Motor Efficiencies. Electric motor horsepower rating will be limited to no more than 125% of the maximum load being served unless a NEMA standard size does not fall within the range, in which case, the next larger NEMA standard motor should be used. Minimum motor efficiencies will conform to the table in appendix H. Standard efficiency motors will be used when the expected operating hours are 750 hours or less per year. High efficiency motors will be used for cases greater than 750 hours.

f. Switchboards. Switchboards will be included in designs for the following applications: (1) where a centrally located switchboard would prevent the need for several separate panelboards; (2) when the length of feeders originating at the switchboards would not require large conductors to prevent excessive voltage drop at terminals of equipment; and (3) for control rooms when control, instrument, or relaying equipment should be located in that central location. The design of switchboard installations will include the following:

(1) Single- or three-line diagrams, as required.

(2) Control schematics or elementary diagrams.

(3) External wiring connection diagrams.

(4) Other drawings required to show details of installation of the switchboard.

g. Panelboards. Care will be exercised in selecting panelboards and in the quantity and location of panelboards to minimize costs while ensuring installation of reliable items of equipment which require a minimum of spare parts and maintenance. Panelboard design guidance follows:

(1) Panelboard schedules will be prepared which show:

(a) A complete description of the panelboard.

(b) Features. Appropriate features of protective elements enclosed, including the ampere-frame size, trip rating, and number of poles of circuit breakers.

(c) Description of Equipment. An adequate description of the equipment supplied through the respective protective devices.

(d) Loading. Loading on each phase bus in volt-amperes, unless equipment supplied is rated in watts only.

(e) Total connected load on each phase.

(f) The total load connected to the panelboard.

(g) Demand Load. The demand load calculated by applying reasonable demand and diversity factors in accordance with guidance in appendix G.

(2) General requirements for panelboards will include the following provisions:

(a) Type. Panelboards will be the dead-front type equipped with bolt-on circuit breakers unless otherwise approved by USAEDH. Stab-on circuit breakers and panelboards equipped with fuses will not be permitted without adequate justification for their use.

(b) Rating. Panelboards should have the minimum AIC rating consistent with the asymmetrical fault-current calculated by the designer to be available at the panelboard supply terminals. The AIC rating should normally be 22,000 amperes or less, with current-limiting fuses considered to limit the fault current to the panelboard when the available current exceeds 22,000 amperes.

(c) Buses. Panelboard buses will be protected against fault currents and overloads by a main circuit breaker, or by the panelboard feeder protective device which is capable of being locked in the open position.

(d) Spare Devices. One spare protective device will be provided for each group of nine (9) protective devices used to supply equipment described in the schedule. Ratings of spare devices will be the same as the majority of circuit breakers or sets of fuses included in the panelboard.

(e) Spaces. "Spaces" will be shown in the schedule when spare and "active" protective devices used initially do not occupy all "pole positions" included in standard sizes of commercially available panelboards.

(f) Number of Circuits. Panelboards will normally be shown and specified in lieu of separately enclosed circuit breakers, or sets of fuses, when the number of circuits originating in the separate enclosures exceeds six (6).

(3) Designs of panelboard installations will satisfy the preceding general guidance and the more specific guidance as follows:

(a) Lighting and Appliance Branch-Circuit Panelboards. Lighting and appliance branch-circuit panelboards will be selected to conform to the definition and description in the NEC and will be included in designs when required to serve single- phase loads from a single-phase supply, or a 3-phase, 4-wire source of power rated at 208/120Y volts or 480/277Y volts. This panelboard is used to distribute power to lighting fixtures rated at 277 volts or less, for single-phase motors rated 1/2 horsepower or less, for convenience receptacles or other general purpose items of equipment with single- or combined-load demands of 24 amperes or less. Other uses are subject to the approval of USAEDH.

(b) Power Panels or Panelboards. Power panels or panelboards will be used when lighting and appliance panelboards are unsuitable to supply utilization equipment items because of circuit load demands exceeding 24 amperes or because utilization equipment requires a 3-phase source of power. Power panels should be equipped for 3-phase, 4-wire supply and distribution to serve 3-phase, 3-wire and 3-phase, 4-wire types of utilization or distribution equipment, either initially or at a future date.

1 Power panels should not be used to supply lighting and appliance panelboards without prior approval of USAEDH. Approval will normally be granted when power panels serve as service-entrance equipment, and in instances when such panels will eliminate increased costs for construction of facilities not deemed essential to accomplishing the missions of a project or installation.

2 Power panels equipped with molded-case circuit breakers or fuses should not be used for critical facilities which are essential to national interests except when they will serve non-essential equipment. In those instances, the use of low-voltage power circuit breakers may be required to protect feeders which supply critical loads to provide increased reliability.

3 Generally, power panels should have circuits rated at or less than 800 amperes. Designers should consider the design of low-voltage power switchgear when a number of circuits have a rating greater than 225 amperes. The intended use of power panels equipped with protective devices exceeding 225 amperes should be coordinated with and approved by USAEDH before proceeding beyond the concept stage of design.

h. Interior Lighting Systems. The design of interior facility lighting is to conform to the AEI. Lighting fixtures should be the types shown in CE Standard Detail 40-06-04 with designs incorporating the optimum methods for energy conservation. An analysis of the different lighting designs will be furnished with design drawings and specifications to justify accuracy and completeness of the designs. The analysis must demonstrate the suitability of the designs to provide quality illumination required to accomplish the work or functional tasks in specific rooms or areas. The analyses will include all information concerning: the project identification, including the name of the area, building, and room number; the average illumination to be maintained, in foot- candles; lamp data and factors associated with the selection of coefficients of utilization and light loss factors; and calculations made to determine the quantity of fixtures. The design analyses will include data shown in tabular form in appendix A to CE Standard Detail 40-06-04. Lighting design layout or arrangement drawings and/or specifications will clearly provide the following information or design considerations:

(1) Room or area identification and dimensions including length, width, and height above the floor or platform to the ceiling or to overhead obstructions.

(2) Relative arrangement, quantity, mounting height, and type of fixture mounting (recessed, surface, or pendant). The quantity and rating of fixtures will also be shown on lighting layout drawings (along with the level of illumination in foot- candles to be maintained in the room or area). Illumination levels in excess of those authorized by the AEI, i.e., those required for the more difficult viewing tasks, will be provided by the Using Agency as task-lighting fixtures.

(3) Fixture ratings including the supply voltage to the fixture and the volt-ampere or watt burden imposed by the different types of fixtures. Temperature ratings will also be provided when fixtures with ballasts are operated in an ambient temperature less than 10 degrees C or above 40 degrees C. Wattage rating of fluorescent bulbs will not exceed 34 watts.

(4) Switching of fixtures to provide the optimum in energy conservation without sacrificing the general illumination needs of the facility. A minimum of one control will be provided for each space enclosed by walls or ceiling-height partitions. However, if the space is greater than 450 ft^2 or 1500 watts, then one control will be provided for an average of 450 ft^2. Optimum use of 3-way or 4-way switches, automatic illumination control, and low-voltage switching devices is required. Switching fixtures from circuit breakers in panelboards and switching of groups of fixtures by lighting contactors should be avoided except when fixtures are installed in hazardous lo- cations. Panelboards used for the switching of fixtures in hazardous locations will be located in a nonhazardous area whenever feasible.

(5) Types of lenses or diffusers (when required to provide the proper symmetrical or asymmetrical light distribution for specific tasks or areas). NEMA types of light distribution patterns will be provided, when applicable. The material, shape, construction, and finish of reflectors will be indicated to ensure proper light distribution for the specific application.

(6) Requirements for personnel safety and protection of the facility from hazards created by explosions or fires.

(7) Flexibility in the design/arrangement so that fixtures can be relocated to accommodate changes during initial construction, or later, to accommodate changes in the work tasks or functional use of the room or area. Flexibility will be incorporated only when it is feasible, can be done safely, and at a warranted expense.

(8) Aesthetics will be considered only when required for proper lighting or color rendition needed to perform work-related tasks. Dimmers, dimming ballasts, etc.,

and less energy-efficient fixtures will be avoided except when required for special work areas, such as conference or meeting rooms.

(9) Stroboscopic effects of fluorescent and high intensity discharge (HID) lighting will be reduced to a minimum. Design drawings and specifications will indicate the method chosen to eliminate stroboscopic effects; the design analysis should indicate the desired results. Fluorescent lighting and stroboscopic effect are troublesome in machine shop, woodworking, and similar areas where revolving machinery is used. Stroboscopic effect can be greatly reduced by one of the methods shown below:

(10) Buildings without a separate programmable or automatically controlled lighting system and those with a utility monitoring and control system (UMCS) will have the contactor wiring incorporated into the electrical design.

(11) One- and three-lamp fluorescent fixtures will be wired in tandem. Wiring will be shown on the drawings.

(12) Fluorescent lamp ballasts will have a Ballast Efficacy Factor (BEF) not less than that shown on table I-1 in appendix I. The BEF is calculated using the formula BEF equals ballast factor in percent / power input where power input equals total wattage of combined lamps and ballasts.

METHOD 1: Use two (2)-lamp fixtures with lead-lag ballasts. (This method is most practical and economical.)

METHOD 2: Use three (3)-lamp fixtures with 3-starters each on separate phases. (This method provides minimum stroboscopic effects.)

Relative levels of Stroboscopic Effect

	Lamp Configuration	Strobe. Level
	200-watt incandescent lamp	= 1
	40-watt incandescent lamp	= 7
1	40-watt fluorescent lamp	=19
2	40-watt, 2-lamp ballast	= 9
3	40-watt, 3 one-lamp ballast connected on separate phase	= 3
3	40-watt, 1 two-lamp and one-lamp ballast all on one phase	= 14

NOTE FOR THE PRECEDING TABLE: Fixtures should be installed two per starter (lead-lag type) where possible. Adjacent fixtures should be connected to separate phases to reduce stroboscopic effect.

i. Special Facilities, Equipment or Systems. Design requirements may vary considerably among a variety of facilities associated with the care and training of mili-tary personnel, such as firing ranges, hospitals, housing, testing, and training facilities. Designers will coordinate design efforts with USAEDH for special facilities, equipment, or systems if design documents referenced do not provide adequate design guidance or requirements.

8-11. COMMON REQUIREMENTS FOR ELECTRICAL POWER DESIGNS. The following are design requirements for either interior or exterior facilities, equipment or systems, as applicable.

a. Power Factor Correction. Power factor correction (PFC) will be considered in instances when existing installations have a system power factor of less than 0.90, and when the power factor can be improved to a cost-effective value greater than 0.90.

(1) Installation of switched PFC capacitors in substations, or in long distribution lines, will be considered for large existing bases or installations. However, the design of such PFC methods will be undertaken only when that method is cost effective and USAEDH approves the proposed design.

(2) Designs of new facilities at existing installations, or designs for new bases, camps, forts, etc., will incorporate more effective methods to conserve energy, reduce peak load demands, and reduce conductor sizes and corresponding costs.

(3) In general, motors rated at and above 5 horsepower will be provided with PFC capacitors when motors are known to have a power factor less than 0.90. Automatic PFC devices should not be considered for inclusion in designs. PFC capacitors will be shown to be connected to motor terminals except when motors will be supplied as a part of a general equipment assembly. In those instances, capacitors will be shown connected to the load terminals of separate starters, or to the load terminals of starters to be installed in a motor control center.

(4) Designs of capacitor circuits will conform to the applicable requirements of the NEC. The reduction of current attributed to the design of PFC will be considered in determining the ampacity of conductors.

b. Ampacity of Aerial Conductors. Ampacity of aerial conductors, except for related service-entrance conductors, must be able to serve the maximum calculated demand requirements in addition to future demands which can be reasonably anticipated for load growth. In general, the ampacity of aerial conductors should not exceed the current calculated by summing the demand of all connected items of equipment.

c. Ampacity of Service-Entrance Conductors. Ampacity of service entrance conductors, rated at or less than 600 volts, should approximate 150% of the maximum current calculated after reasonable demand and diversity factors are used to estimate the maximum current demands. Larger ampacities are subject to the approval of USAEDH.

d. Ampacity of Feeders. The word "feeders" has the same meaning as defined in the NEC. Ampacity of feeders should also approximate 150% of the maximum current demands calculated in accordance with guidance in appendix G. This will allow for reasonably expected future increases in current demands. The ampacity of insulated feeders and branch-circuit will be selected based on the following guidance related to conductor sizing and temperature rating of conductor insulation.

(1) The ampacities of feeder and branch circuit conductors will be calculated and selected to meet the minimum requirements of the NEC. Ampacities will conform with the UL Electrical Construction Materials Directory, when circuit protective devices are specified to be UL-listed. This will require that insulated conductors have insulation rated 60 degrees C for circuits rated at 100 amperes or less, and rated at or above 75 degrees C when circuits are rated in excess of 100 amperes.

(2) Ampacities will be altered when insulation with ratings of 90 degrees C or above are specified. Insulation with high temperature ratings will be specified to suit the recommendations of equipment manufacturers, or when insulated conductors are installed in a location subject to high ambient temperatures.

e. Ampacity of Branch-Circuit Conductors. Ampacity and temperature rating of branch-circuit conductors will be determined during design based on the above guidance for feeder conductors, and should approximate 125% of the maximum demand calculated for branch circuit wiring. Ampacities will be based on the use of copper conductors. Use of aluminum or copper-clad conductors will not be permitted for branch circuits. Ampacities will be increased when required to limit voltage drop to an acceptable value.

f. Voltage Drop. Voltage drop, or the reduction in voltage between the power source and connected items of equipment, will not exceed the percentages shown in TM 5-811-1 for subtransmission, distribution, service, and utilization conductors or equipment, or as required by the minimum provisions of the NEC. Design analyses for the various systems will include complete and accurate calculations to justify the selection of the types, sizes, and consequent ampacities and voltage reductions associated with the design.

g. Wiring Methods. Wiring methods will be shown or specified to conform to the guidance in applicable TM's, requirements of the guide specification for ELECTRICAL WORK -INTERIOR, and will otherwise conform to the minimum requirements of the NEC.

h. Ground-Fault Protection. Ground-fault protection will be incorporated into designs for the safety of personnel, as required by the NEC, and in instances when, following completion of the facility, personnel would be working in an outdoor environment while using electrical items of equipment, or handling energized flexible cables which serve as an extension for electrical power service. Ground-fault protection will be provided by using circuit breakers or receptacles equipped with a ground-fault circuit- interrupting device rated to operate for ground-fault currents of 20 milliamperes.

I. Power Receptacles, Cover Plates, and Wiring of Receptacles. Power receptacles that supply power to electrical appliances, portable equipment or tools, and extension cords or cables, will have a grounding pole. Receptacles will have the grounding pole incorporated into the body of each receptacle, along with other poles required to supply power to connected items of equipment. The arrangement of poles will suit the arrangement of poles on plugs commonly supplied on appliances, portable equipment, or on extension cords.

(1) Receptacles will be standard NEMA type unless others are required and approved by USAEDH for specialized applications. General purpose receptacles and cover plates will be the same color. Receptacles and cover plates will be ivory color except when a different color is required to match paneling or paint selected.

(2) Outdoor receptacle covers will have spring-loaded or screw-on caps.

(3) Poles or terminals of receptacles used to supply electrical power to connected items of equipment will be wired to suit the current and voltage ratings of loads served by the receptacles.

(4) Metallic raceways will not be used as a ground-current path for branch circuits which supply receptacles. Separate grounding conductors will be provided. This is because high-ground-path-impedance at the raceway joints prevents operation of circuit protective devices in situations where the joints are not properly bonded or where the bond is removed during maintenance or deteriorates in the presence of moisture or contaminants.

(5) The neutrals of power supplies will not be used as grounding conductors unless permitted by the NEC and approved by USAEDH.

j. Ground Systems. Grounding systems will be designed to limit the resistance-to-ground value to 25 ohms or less depending on the type of installation, equipment, or special circumstances.

(1) Grounding designs for main electric supply stations, major substations, and line-surge-arrester installations will provide a maximum resistance-to-ground of 5 ohms.

(2) Grounding systems for hazardous facilities and for facilities containing computers or other surge-sensitive electronic equipment will be designed to achieve a maximum resistance-to-ground of 5 ohms or less. Equipment stipulated to have a single-point ground will have a green insulated ground conductor connected to a single point in the facility grounding system.

(3) Design analyses will contain calculations required to demonstrate compliance with the resistance-to-ground requirements.

(4) Designs will show the use of bare copper conductors and copper or copper-clad ground rods, or other grounding electrodes approved by USAEDH to provide the minimum resistance-to-ground required by the specific application. The AWG or Thousand Circular Mils (kCM) size of copper ground conductors, included in grounding designs, will be increased in size and ampacity when bare buried copper cables are subject to a reduction in size and ampacity because of chemical or electrolytic actions, which would tend to reduce the resistance-to-ground effectiveness of the grounding installation.

(5) Designs will consider grounding systems when facilities are constructed or modified in a location subject to lightning storms, and when those facilities are classified as hazardous or designed to house sensitive electronic equipment. This will generally require that all equipment within a facility be grounded to the same facility grounding system, and that separate facility grounding systems be electrically connected to obtain an equipotential ground system for the project or installation. Separate grounding of facilities or equipment within facilities can cause a large potential gradient between separate and electrically isolated grounding and lightning protection systems during lightning strikes. This can propagate the detrimental effects of lightning, causing more damage, and prolonged inoperability of normal facility functions. Therefore, special design considerations will be given to the design of equipotential ground systems for the types of facilities described, as well as to associated lightning protection systems.

(6) Designs will include provisions to mitigate the harmonic currents of nonlinear loads as described in TM 5-811-1 and TM 5-811-2.

8-12. COST EFFECTIVENESS OF DESIGNS. The cost effectiveness of designs will be based on the life cycle cost over the expected life of equipment, materials, facilities or project, as applicable. A life cycle cost study will be prepared and included in the design analyses with options capable of fulfilling power requirements with equal reliabil- ity but at different annual costs. Designs will be prepared which have the lowest life cycle cost. Designs will permit the use of single subtransmission lines, radial feeders, single-ended substations, etc., to minimize the cost of installation of facilities or projects. However, projects of significant importance to national defense interests may warrant the use of more expensive installations because of requirements for increased availability, maintainability, and reliability of electrical power systems. The cost effec-tiveness of those and other designs will minimize the cost of installing electrical power supply, distribution, and utilization systems while ensuring that designs conform to the design criteria for the facilities or projects required by the scope of work.